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Thermal-Epithermal eXperiments – Hafnium Experiment Performed at the DOE's National Criticality Experiments Research Center (NCERC)

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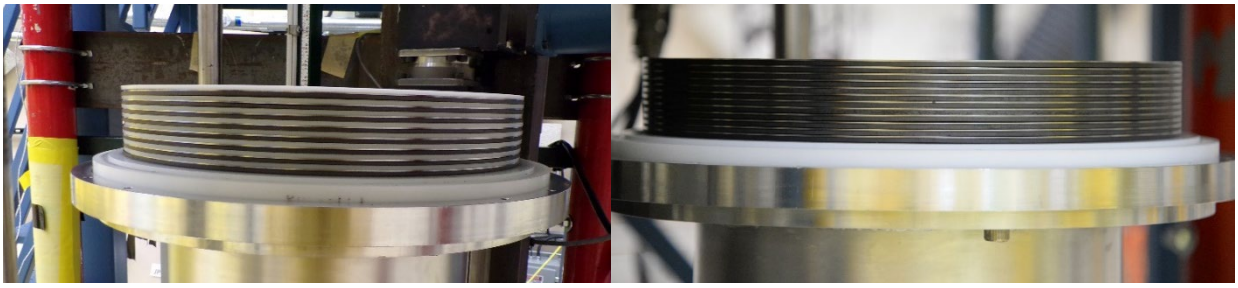
The Thermal-Epithermal eXperiments (TEX) – Hafnium (TEX-Hf) experiments were completed in October 2022 at the DOE National Criticality Experiments Research Center (NCERC) at the Nevada National Security Site (NNSS). This measurement campaign provides seven unique configurations that can be used to validate the neutron absorption and scattering cross sections of hafnium in a highly enriched uranium (HEU) system. Hafnium is a strong neutron absorber important for marine propulsion systems. Mike Zerkle of the Naval Nuclear Laboratory (NNL) states, "The experiments were requested by Naval Reactors to provide a suite of unclassified, clean, and well-characterized benchmarks to drive improvements to hafnium nuclear data." The experiments were a collaboration between Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and NNL, funded by the Nuclear Criticality Safety Program (NCSP). The Hf was procured directly by NNL and provided for the experiment.

The TEX-Hf experiments consist of layers of bare HEU Jemima plates, polyethylene moderator plates, hafnium absorber plates, and polyethylene reflectors. The neutron spectra of the configurations spanned from thermal through the intermediate energy region to fast. This was achieved by varying the thickness of the polyethylene moderator plates. The TEX-Hf experiments were conducted on the Comet vertical lift assembly machine at NCERC, which allows the critical mass to be loaded in two portions and brought together remotely.

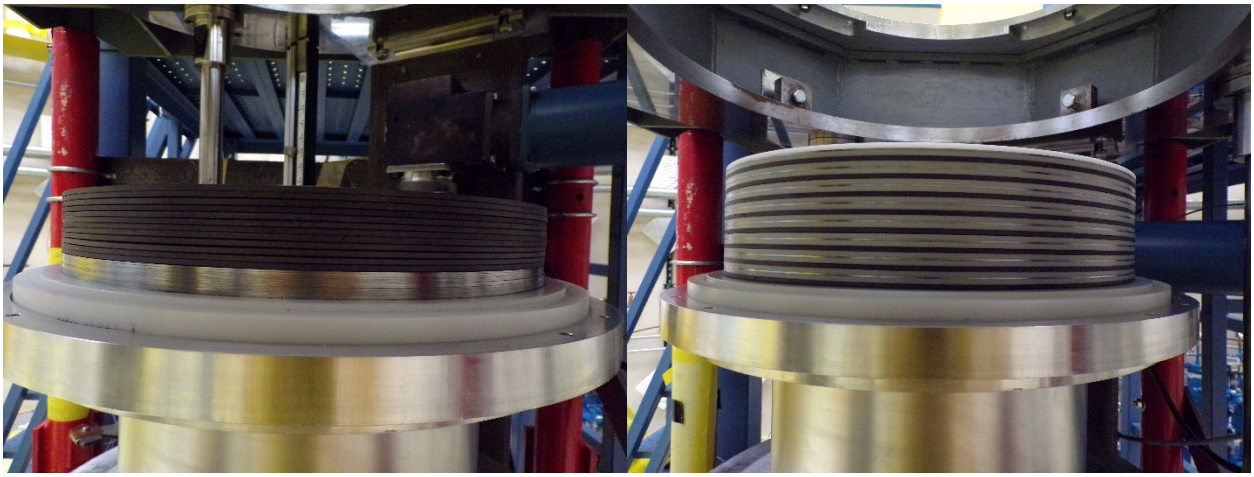
The diameter of the core was 15 inches with a one-inch reflector on all sides to reduce the critical mass. Each configuration had repeated layers of HEU, Hf, and polyethylene. These layers formed a unique repeating unit for each configuration. The HEU consisted of 0.118-inch thick Jemima plates. The inventory includes plates that are solid as well as plates with inner holes of 2.5 inch, 6 inch, and 10 inch diameter. The selection of plates could be used to adjust reactivity. The Hf plates were solid and 0.040 inches (1 mm) thick. The polyethylene plates had thicknesses of 1/8 inch, 1/4 inch, 1/2 inch, and 1-1/2 inches.

The figure on the left shows the bottom stack for the 1 ½-inch polyethylene standard stacking configuration without the side reflector. The figure on the right shows the critical configuration through a camera.

The figure on the left shows the bottom stack for the ½-inch polyethylene standard stacking configuration without the side reflector. The figure on the right shows the ¼-inch polyethylene standard stacking configuration without the side reflector.



The figure on the left shows the bottom stack for the 1/8-inch polyethylene standard stacking configuration without the side reflector. The figure on the right shows the 0-inch polyethylene standard stacking configuration without the side reflector.



The figure on the left shows the bottom stack for the 0-inch polyethylene bunched Hf configuration without the side reflector. The figure on the right shows the ¼-inch polyethylene sandwich stacking configuration without the side reflector.

Measurements consisted of excess reactivity measurements of critical configurations. As well as physical measurements for use in the development of a benchmark evaluation. For some configurations a reproducibility measurement was also performed where the full stack was unstacked and restacked to repeat the excess reactivity measurement.

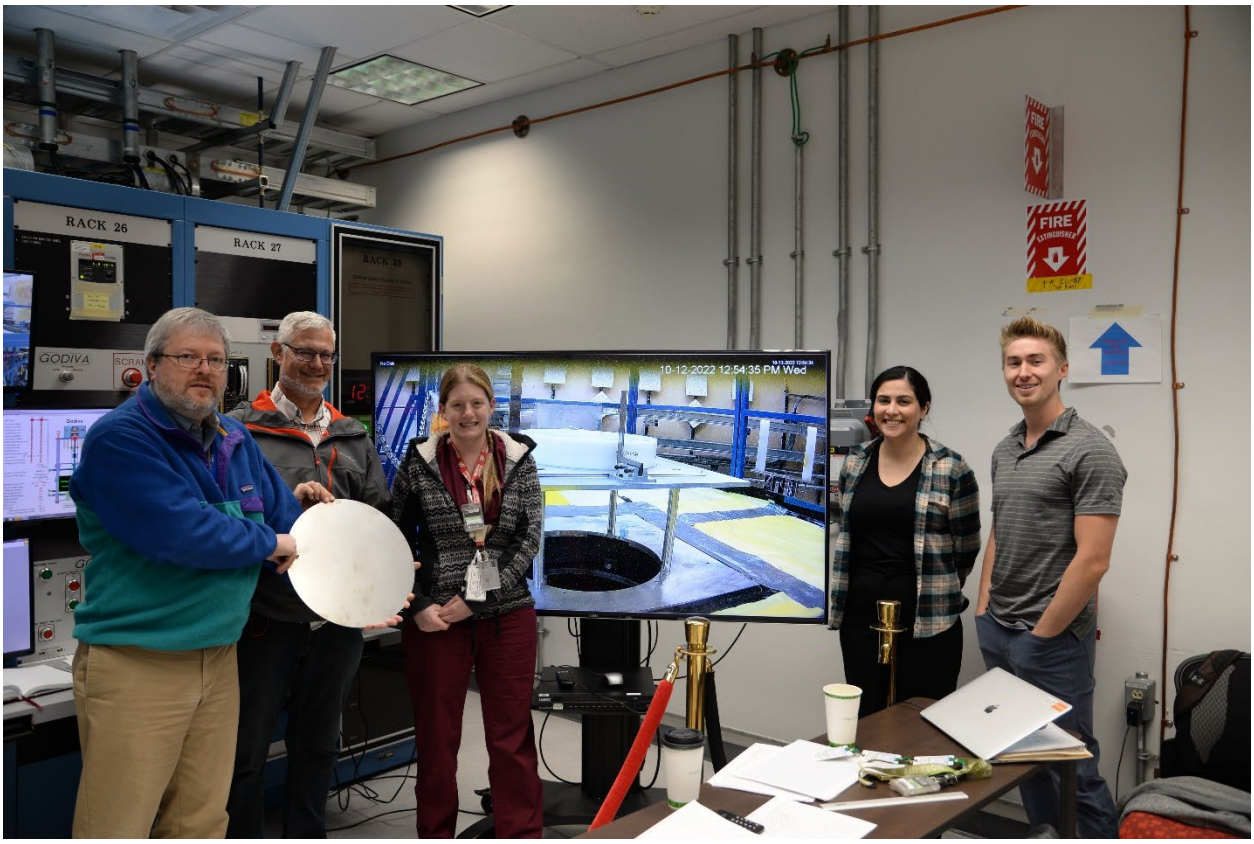
The TEX experiments compare a critical system with a diluent, such as Hf, to a similar system without the diluent. The precursor experiments (TEX-HEU Baseline) were completed in Spring 2020. The design of the experiment was performed using MCNP6® with an emphasis on maximizing sensitivity to the hafnium absorption and scattering cross sections in the desired energy ranges and achieving a critical system with a height to diameter ratio of approximately one and less than 1.5.

The TEX-Hf experiments will be evaluated by LLNL and submitted to the International Criticality Safety Benchmark Evaluation Project (ICSBEP) in fiscal year 2024.

Table 1 gives preliminary results for the seven measured configurations, including the HEU mass of the critical configuration, measured reactor period and associated excess reactivity. Further analysis of the TEX-Hf experiments and experimental data will continue in the future and calculations will be performed to analyze experimental and measurement uncertainties.

Table 1. TEX-Hf Preliminary Data

Configuration	HEU Mass (kg)	Measured Reactor Period (seconds)	Associated Excess Reactivity (cents)
1/8” Hf Standard	99.470	64.8	13.2
1/4” Hf Standard	82.957	25.4	24.2
1/2” Hf Standard	63.917	122.9	8.1
1-1/2” Hf Standard	70.372	84.5	10.9
0” Hf Standard	135.574	59.2	14.1
0” Hf Bunched	124.803	73.8	12.0
1/4” Hf Sandwich	88.528	50.7	15.7



Some members of the TEX-Hf Team in the NCERC Comet Control Room [left to right: Michael Zerkle (NNL), John Miller (SNL), Kelsey Amundson (LANL), Ruby Araj (LLNL), Jesse Norris (LLNL)]. Not shown: Rene Sanchez, Travis Grove, Jesson Hutchinson, Theresa Cutler, Alex McSpaden, Nick Thompson (LANL) and Eric Aboud (LLNL).

Acknowledgements
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